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DFA MODEL THROUGH ASSEMBLY CONTACT DATA AND GEOMETRICAL FEASIBILITY TESTING

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ABSTRACT

The concept of Design for Assembly (DFA) assure cost effective assembly process by minimizing the assembly efforts. Part count reduction is one of the primary objective of DFA, which reduces the number of assembly levels and assembly tooling. However reducing part count with modified part geometries do not allow to follow the same assembly sequence that of used earlier. In this contest a framework for DFA coupled with assembly sequence planning to minimize the number of parts using the assembly coherence data and material compatibility testing without disturbing the functionality of the product is presented.

Key words: Design for Assembly, Assembly Contact Data, Geometrical Feasibility Testing, Assembly Feasibility Testing, Assembly Feasibility Contact.

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1. INTRODUCTION

Mechanical assembly process consumes 30-40% overall manufacturing cost [1]. The concept of DFA further minimizes the assembly cost by reducing the total number of parts with modified topologies and without disturbing the functionality of the product intended to perform [2]. As the number of parts is reduced, the need of tolerances also minimized and further economizes the assembly process [3-5]. Although assembly tooling with reconfigurable manufacturing influence the overall product cost, the present research is focused on need of DSP and ASP at early stages of redesign process.

Assembly sequence generation methods basically focused on determining one or multiple feasible and stable assembly sequences considering various assembly predicates [6-10]. Considering all necessary assembly predicates assure appropriate assembly sequence that can be physically possible [11].

Retrieving all the necessary assembly attributes from computed aided design (CAD) models through CAD interfacing has been practiced by many researchers. Assembly contact relations, conflict detection techniques were used to generate liaison matrix [12-13]. Bahubalendruni presented geometric feasibility testing using part bounding box coordinates using different CAD data exchanging formats [14-16]. Assembly stability is one of the essential criterion to be followed to ensure stable assembly subset, Smith initially proposed concept of stability using soft and hard connections, further Bahubalendruni enhanced classified hard connections into two categories [17-19]. Mechanical feasibility is yet another assembly predicate ensures the geometric feasibility of mechanical connectors De Mello [20-21].

There exist several knowledge based assembly sequence generation methods to generate all set of assembly sequence using assembly attribute data [22-24]. Several researchers focused on obtaining optimal assembly sequences using artificial intelligence techniques [25-29]. However the application of assembly sequence planning is not extended towards DFA. In the present research, all set of assembly sequences are generated and further assembly coherence, material compatibility and functional requirements were applied to test the possibility of minimizing total number of parts.

2. OVERVIEW OF PART CONCATENATION METHOD

Part concatenation method builds assembly subsets starts from 2-part assembly subset generation to higher lever subset generation till the number of parts in the subset reaches to total number of parts in the given product. The process is iterated by appending a non-existent part after qualifying all necessary predicates. A brief flow diagram of part concatenation method is shown in figure 1. The method considers all necessary assembly predicates to generate all set of feasible and stable assembly sequences.

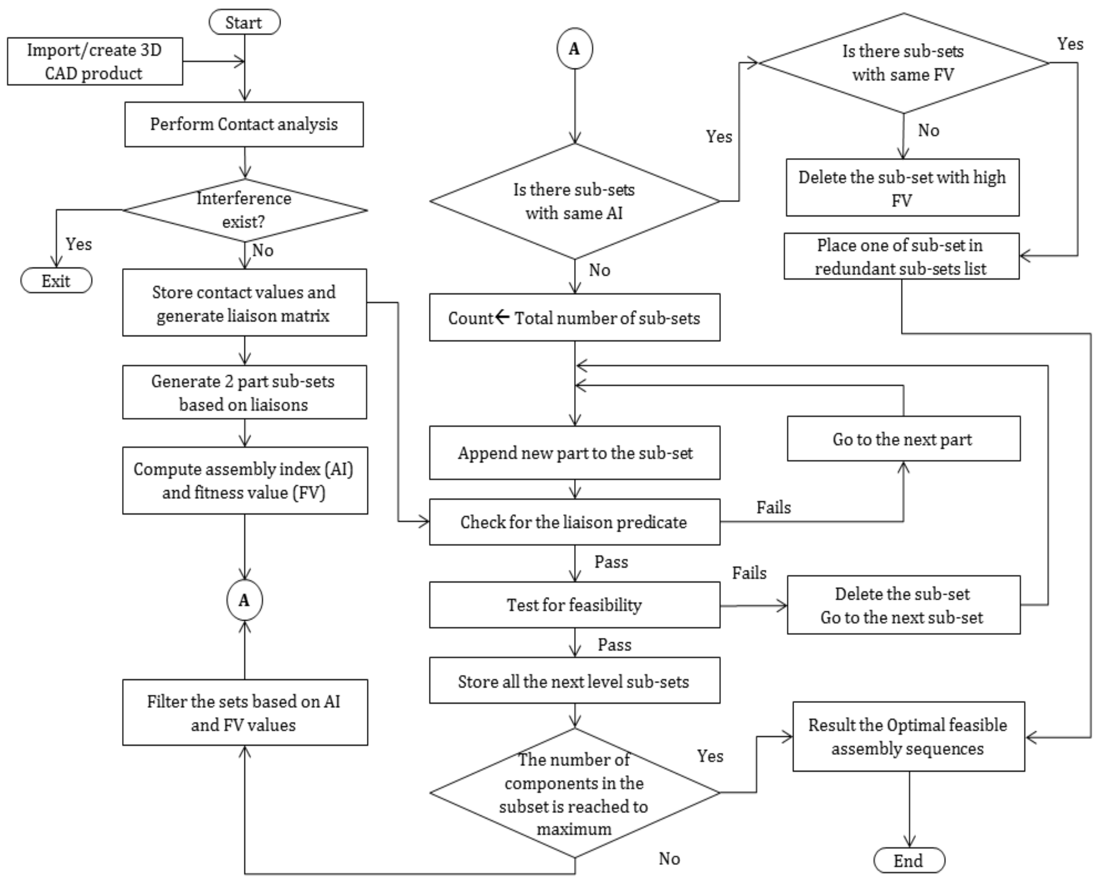

Figure 1 Part concatenation method to generate all set of feasible assembly sequences

The necessary assembly information has been extracted using CAD based extracting techniques (Bahubalendruni, 2014a& 2015c &2016b &2016d). The method is implemented on a pen assembly composed of 5 parts shown in Figure 2 and the resulted intermediate level assembly subsets are shown in Table 1.

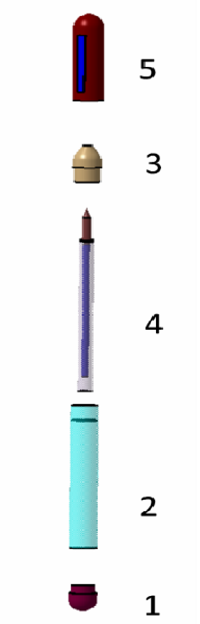

Figure 2 Exploded view of 5-part pen assembly

Table 1 List of intermediate assembly subsets for 5-part pen assembly

2 Part subsets	3 Part subsets	4 Part subsets	5 Part subsets
1-2	1-2-3	1-2-3-5	1-2-4-3-5
1-4	1-2-4	1-2-4-3	1-4-2-3-5
2-1	1-2-5	1-2-4-5	2-1-4-3-5
2-3	1-4-2	1-4-2-3	4-3-2-1-5
2-5	1-4-3	1-4-2-5	4-3-2-5-1
3-2	2-1-3	1-4-3-5	4-3-5-2-1
3-5	2-1-4	2-1-3-5	
4-3	2-1-5	2-1-4-3	
5-2	2-3-1	2-1-4-5	
5-3	2-3-5	2-3-1-5	
	2-5-1	2-3-5-1	
	3-2-1	3-2-1-5	
	3-2-5	3-2-5-1	
	3-5-2	3-5-2-1	
	4-3-2	4-3-2-1	
	4-3-5	4-3-2-5	
	5-2-1	4-3-5-2	
	5-3-2	5-3-2-1	

3. DESIGN FOR ASSEMBLY

All set of feasible sequences along with possible direction matrix is considered at this stage to determine possible minimum theoretical number of parts. For this purpose, three different filters are considered related to product topology, materials and product functionality.

3.1. Assembly Coherence and Geometric Feasibility Filter

A pair of parts can be merged together to create a new part with modified geometry, if there exist at least one surface contact between them provided both of the parts possess same feasible assembly direction. At this phase all such pairs are identified from the all set of feasible assembly subsets created through part concatenation method.

3.2. Material Compatibility Filter

Besides the geometric feasibility testing, the pair of the parts should also made up of same material else one of part material can be applied to other part. Basic material compaitibility testing will be done based on the mating parts and working atmosphere of the merged part taking environmental conditions into consideration.

3.3. Functional Requirement Filter

Though the pair of parts are in contact and possess material compatibility, it must also not leads to obstruction of assembly functionality intended to perform. Hence assembly functionality is applied as a final filter to determine the qualified part pairs.

All the DFA filters have been applied on the feasible assembly sequences and the feasible DFA based assemblies are listed in Table.2.

Table 2 DFA based assemblies are listed

S. No.	Assemble Sequence	Direction matrix	Assembly coherence and feasibility	Material Compatibility	Assembly Functional Requirement	DFA resulted sequence
1	1-2-4-3-5	z-,z-,z-,z-,z-	Yes	Yes	Yes	(1-2)-4-3-5
2	1-4-2-3-5	z-,z-,z-,z-,z-	Yes	Yes	Yes	1-4-(2-3)-5
3	2-1-4-3-5	z+,z+,z-,z-,z-	Yes	Yes	Yes	(2-1)-4-3-5
4	4-3-2-1-5	z-,z-,z+,z+,z-	Yes	Yes	Yes	4-3-(2-1)-5
5	4-3-2-5-1	z-,z-,z+,z-,z+	Yes	No	No	
6	4-3-5-2-1	z-,z-,z-,z+,z+	Yes	Yes	Yes	4-3-5-(2-1)

4. CONCLUSION

The concept of DFA implementation before assembly sequence generation leads to inappropriate results, most of the sometimes the resulted is practically an infeasible assembly configuration. Hence an assembly sequence planning based DFA framework is proposed and illustrated through an example product. The results indicate that assembly coherence and feasibility filter, material compatibility filter and assembly functionality filter results an appropriate feasible assembly configuration with reduced number of parts and minimized assembly efforts. The proposed method results multiple feasible alternate possible solutions to the user.

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